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BBN
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FILE TRANSFER PROTOCOL

Meeting Announcement and a New Proposed Document

Attached is a new proposal for a File Transfer Protocol. The document is an extensive update to RFC 354 and, I believe, incorporates solutions to most of the objections to RFC 354.

It now seems appropriate to make another attempt to reach final agreement on FTP. Accordingly, I am calling a meeting of interested parties, to be held at BBN on March 16, for discussion of this and other proposals.

This note is directed to the network community at large, rather than specifically to the old FTP committee, because I don't believe that the FTP committee membership includes all the individuals who have contributed to the current state of FTP design. Nevertheless, it is intended that the meeting proceed from the current state, rather than bringing new members up-to-speed. Prospective attendees should therefore be familiar with at least the following documents:

RFC 354
RFC 385
RFC 414
RFC 418
RFC 438

Anyone wishing to attend this meeting should contact Alex McKenzie (NIC Ident aam) at BBN, 50 Moulton Street, Cambridge, Mass. 02138. My telephone number is:

(617) 491-1850 ext. 441

When there is some indication of the number of individuals planning to attend, a meeting room will be reserved and more specific information will be directed to attendees.

AAM/jm
Attach.

PROPOSED FILE TRANSFER PROTOCOL

This document is the outcome of a meeting held 25 January 1973 in Cambridge, Massachusetts, by the following people:

Abhay Bhushan (MIT - DMCG)
Bob Bressler (BBN - NET)
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The basis of the document is RFC 354 with considerations drawn from RFC's 385, 414, 418, and 438 and personal communication with network participants.

PROPOSED FILE TRANSFER PROTOCOL

I. INTRODUCTION

The File Transfer Protocol (FTP) is a protocol for file transfer between HOSTs (including terminal IMPs), on the ARPA Computer Network (ARPANET). The primary function of FTP is to transfer files efficiently and reliably among HOSTs and to allow the convenient use of remote file storage capabilities.

The objectives of FTP are 1) to promote sharing of files (computer programs and/or data), 2) to encourage indirect or implicit (via programs) use of remote computers, 3) to shield a user from variations in file storage systems among HOSTs, and 4) to transfer data reliably and efficiently. FTP, though usable directly by a user at a terminal, is designed mainly for use by programs.

The attempt in this specification is to satisfy the diverse needs of users of maxi-HOSTs, mini-HOSTs, TIPs, and the Datacomputer, with a simple, elegant, and easily implemented protocol design.

This paper assumes knowledge of the following protocols:

1) The HOST-HOST Protocol (NIC #8246)
2) The Initial Connection Protocol (NIC #7101)
3) The TELNET Protocol (NWG/RFC #318, NIC #9348)

II. DISCUSSION

In this section, the terminology and the FTP model are discussed. The terms defined in this section are only those that have special significance in FTP.

II.A Terminology

ASCII	The USASCII character set as defined in NIC #7104. In FTP, ASCII characters are defined to be the lower half of an eight bit code set (i.e., the most significant bit is zero).
access controls	Access controls define users' access privileges to the use of a system, and to the files in that system. Access controls are necessary to prevent unauthorized or accidental use of files. It is the prerogative of a server-FTP process to provide access controls.
byte size	The byte size specified for the transfer of data. The data connection is opened with this byte size. Data connection byte size is not necessarily the byte size in which data is to be stored in a system, and may not be related to the structure of data.
data connection	A simplex connection over which data is transferred, in a specified byte size, mode and type. The data transferred may be a part of a file, an entire file or a number of files. The data connection may be in either direction (server-to-user or user-to-server).
data socket	The socket on which a User-FTP process "listens" for a data connection.
EOF	The end-of-file condition that defines the end of a file being transferred.
EOR	The end-of-record condition that defines the end of a record being transferred.
error recovery	A procedure that allows a user to recover from certain errors such as failure of either HOST system or transfer process. In FTP, error recovery may involve restarting a file transfer at a given checkpoint.

FTP commands	A set of commands that comprise the control information flowing from the user-FTP to the server-FTP process.
file	An ordered set of computer data (including programs) of arbitrary length uniquely identified by a pathname.
mode	The mode in which data is to be transferred via the data connection. The mode defines the data format including EOR and EOF. The transfer modes defined in FTP are described in Section III.C.
NVT	The Network Virtual Terminal as defined in the ARPANET TELNET Protocol.
NVFS	The Network Virtual File System. A concept which defines a standard network file system with standard commands and pathname conventions. FTP only partially embraces the ~~NFS~~ NVFS concept at this time.
pathname	Pathname is defined to be the character string which must be input to a file system by a user in order to identify a file. Pathname normally contains device and/or directory names, and file name specification. FTP does not yet specify a standard pathname convention. Each user must follow the file naming conventions of the file systems he wishes to use.
record	A sequential file may be structured as a number of contiguous parts called records. Record structures are supported by FTP but are not mandatory.
reply	A reply is an acknowledgment (positive or negative) sent from server to user via the TELNET connections in response to FTP commands. The general form of a reply is a completion code (including error codes) followed by an ASCII text string. The codes are for use by programs and the text is for human users.
server-FTP process	A process or set of processes which perform the function of file transfer in cooperation with a user-FTP process. The server-FTP process must interpret and respond to user commands and initiate the data connection.

server site — A HOST site which has a server-FTP process.

server-TELNET — A TELNET process which listens on a specified socket for an ICP initiated by a user-TELNET, and performs in accordance with the ARPANET TELNET Protocol.

TELNET connections — The full-duplex communication path between a user-TELNET and a server-TELNET. The TELNET connections are established via the standard ARPANET Initial Connection Protocol (ICP).

type — The data representation type used for data transfer and storage. Type implies certain transformations between the time of data storage and data transfer. The representation types defined in FTP are described in Section III.B.

user — A process on behalf of a human being or a human being wishing to obtain file transfer service.

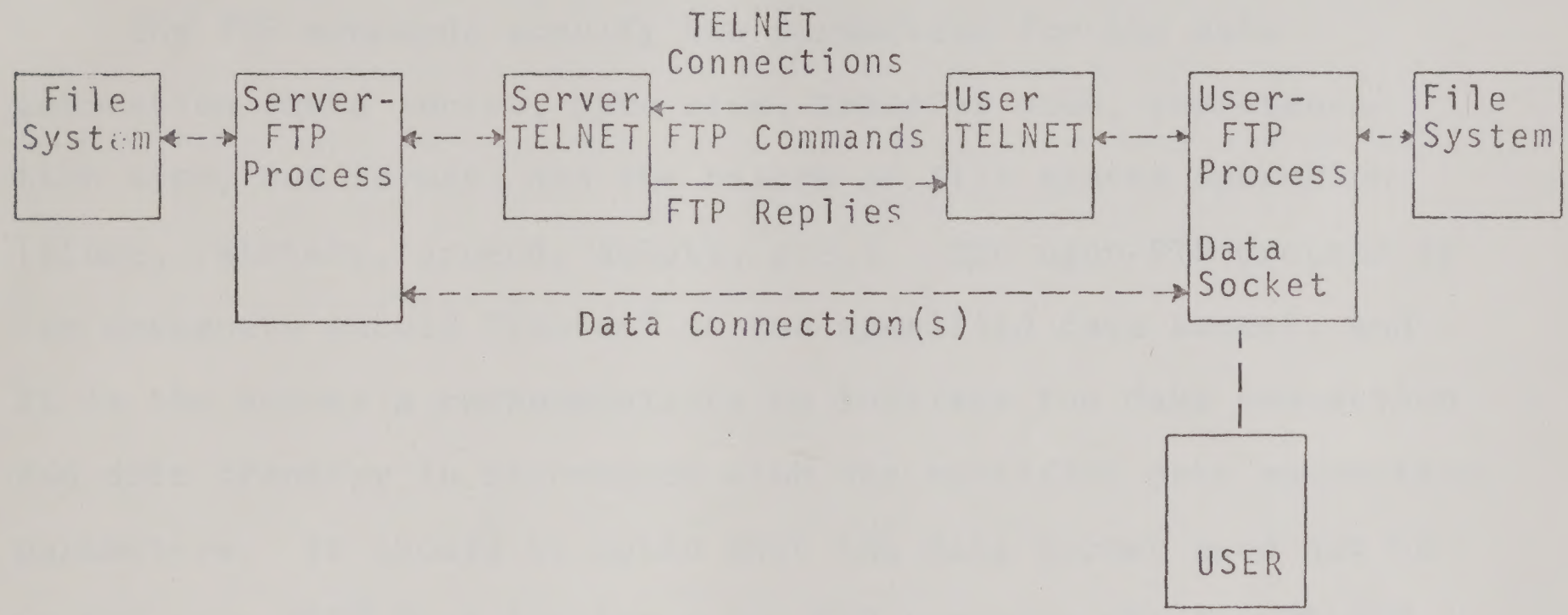
user site — A HOST site satisfying any of the following conditions: 1) The site where a user is located, 2) a site where a user-FTP process is located, 3) a site to which a data connection is made by a server. In the normal case, the sites defined by 1, 2, and 3 are the same site, but nothing in FTP requires that this be so.

user-FTP process — A process or set of processes which perform the function of file transfer in cooperation with a server-FTP process. The user-FTP process 1) initiates the ICP (via a user-TELNET), 2) initiates FTP commands and 3) "listens" on the data socket for the data connection. In some obvious cases (use from TIPs and other mini-HOSTs) a user-FTP process will be subsumed under the term "user".

user-TELNET — A TELNET process which initiates an ICP to a specified server-TELNET socket, and performs in accordance with the ARPANET TELNET protocol.

II.B The FTP Model

With the above definitions in mind, the following model (shown in Figure 1) may be diagrammed for an FTP service.



Notes: 1. The data connection may be in either direction.

2. The data connection need not exist all of the time.

3. The distinctions between user-FTP and user-TELNET, and between server-FTP and server-TELNET may not be as clear-cut as shown above. For example, a user-TELNET may be directly driven by the user.

FIGURE 1 Model for FTP Use

In the model described in Figure 1, the user-TELNET initiates the TELNET connections. Standard FTP commands are then generated by the user and transmitted to the server site via the TELNET connections. FTP commands are in ASCII, in accordance with NVT conventions and the TELNET protocol. Note that commands

may be initiated by the user directly through the user-TELNET or via a user-FTP process. Standard replies are sent from the server to the user in response to the commands over the TELNET connections.

The FTP commands specify the parameters for the data connection (data socket, byte size, transfer mode, representation type, and format) and the nature of file system operation (store, retrieve, append, delete, etc.). The user-FTP process or its designate should "listen" on the specified data socket, and it is the server's responsibility to initiate the data connection and data transfer in accordance with the specified data connection parameters. It should be noted that the data socket need not be in the same HOST that initiates the FTP commands via the TELNET connections, but the user or his user-FTP process must ensure a "listen" on the specified data socket. A practical example of such file transfer to third HOSTs is a maxi-HOST user (who may actually be a TIP user) wishing to transmit a file to or from an I/O device attached to a TIP. It should also be noted that two data connections, one for send and the other for receive, may exist simultaneously.

The protocol requires that the TELNET connections be open while data transfer is in progress. It is the responsibility of the user to close the TELNET connections when finished using the FTP service. The server may abort data transfer if the TELNET connections are closed.

III. DATA TRANSFER FUNCTIONS

Data and files are transferred only via the data connection. The transfer of data is governed by FTP data transfer commands received on the TELNET connections. The data transfer functions include establishing the data connection to the specified data socket in the specified HOST (using the specified byte size), transmitting and receiving data in the specified representation type and transfer mode, handling EOR and EOF conditions, and error recovery (where applicable).

III.A Establishing Data Connection

The user site shall "listen" on the specified data socket, prior to sending a transfer request command. The FTP request command determines the direction of data transfer, and the socket number (odd or even) which is to be used in establishing the data connection. The server on receiving the appropriate store or retrieve request shall initiate the data connection to the specified user data socket in the specified byte size (default byte size is 8 bits), and send a reply indicating that file transfer may proceed. Prior to this reply, the server should send a reply indicating the server socket for the data connection. The user may use this server socket information to ensure the security of his data transfer. The server may send this reply either before or after initiating the data connection.

The byte size for the data connection is specified by the BYTE command. It is not required by the protocol that servers

accept all possible byte sizes. The use of various byte sizes is for efficiency in data transfer and servers may implement only those byte sizes for which their data transfer is efficient. It is, however, required that servers implement at least the byte size of 8 bits.

After the data transfer is completed, it is the server's responsibility to close the data connection, except when the user is sending the data. In stream mode the sender must close the data connection to indicate EOF, i.e., completion of the transfer. Closing the connection is a server option except under the following conditions:

1) The server receives an abort command from the user.
2) The socket or the byte size specification is changed by the user.
3) The TELNET connections are closed.
4) An irrecoverable error condition occurs.

It should be noted that if none of the above conditions occur it is possible to maintain two simultaneous data connections, for send and receive.

III.B Data Representation and Storage

Data is transferred from a storage device in sending HOST to a storage device in receiving HOST. Often it is necessary to

perform certain transformations on the data because data storage representations in the two systems are different. For example, NVT-ASCII has different data storage representations in different systems. PDP-10's generally store NVT-ASCII as five 7-bit ASCII characters, left-justified in a 36-bit word. 360's store NVT-ASCII as 8-bit EBCDIC codes. Multics stores NVT-ASCII as four 9-bit characters in a 36-bit word. It may be desirable to convert characters into the standard NVT-ASCII representation when transmitting text between dissimilar systems. The sending and receiving sites would have to perform the necessary transformations between the standard representation and their internal representations.

A different problem in representation arises when transmitting binary data (not character codes) between HOST systems with different word lengths. It is not always clear how the sender should send data, and the receiver store it. For example, when transmitting 32-bit bytes from a 32-bit word-length system to a 36-bit word-length system, it may be desirable (for reasons of efficiency and usefulness) to store the 32-bit bytes right-justified in a 36-bit word in the latter system. In any case, the user should have the option of specifying data representation and transformation functions. It should be noted that FTP provides for very limited data type representations. Transformations desired beyond this limited capability should be performed by the user directly or via the use of the Data Reconfiguration Service

(DRS, RFC #138, NIC #6715). Additional representation types may be defined later if there is a demonstrable need.

Data representations are handled in FTP by a user specifying a representation type. The type may also imply a transfer byte size. For example, in ASCII representation, the transfer byte size should be 8 bits, and any other byte size specification will result in cancellation of the transfer request. In Image and Local Byte representations ~~the~~ any byte size ~~specified by the BYTE command is to be used.~~ is possible. The following data representation types are currently defined in FTP:

1. ASCII — The sender converts data from its internal character representation to the standard NVT ASCII form. The receiver converts the data from the standard form to its own internal form. The data is transferred in the standard form. The transfer byte size must be 8 bits. This type would be used for transfer of text files. This is the default type, and it is recommended that this type be implemented by all.

2. EBCDIC — The sender transfers data using the EBCDIC character code and 8-bit transfer byte size. This type may be used for efficient transfer of EBCDIC files between systems which use EBCDIC for their internal character representation.

3. Image — The sender transforms data from contiguous bits to bytes for transfer. The receiver transforms the bytes into bits, storing them contiguously independent of the byte size chosen for data transfer. With record structure and block mode, the server might need to pad each record for convenient storage. This padding is allowed at the end of a record, and should be remembered by the server so it will be stripped off when

the file is retrieved by the user. The padding transformation should be well publicized by the server in case the user processes his file at the server site. Typical uses for the Image type are transfer of executable programs between like machines, and transfer of binary (non-text) data. It is recommended that this type be implemented by all for some byte size, preferably including the 8 bit byte size.

4. Local Byte — This representation allows for efficient storage, use, and retrieval of data. The manner in which data is to be transformed depends on the byte size for data transfer, and the particular HOST being used. The transformation scheme for different byte size is to be well publicized by all server sites. This transformation shall be invertible (i.e., if a file is stored using a certain transfer byte size, an identical file must be retrievable using the same byte size and representation type). It is the user's responsibility to keep track of the representation type and byte size used for his transfer. Typical uses of the Local Byte type are in efficient storage and retrieval of files, and transfer of structured binary data. This type may be identical to the Image type for byte size which are integral multiples of or factors of the computer word length.

Representation type may also be affected by another attribute, the format. For example, some printers can use ASA (Fortran) vertical format control procedures to transform printed data of type ASCII or EBCDIC. Currently format may take one of two values.

1. Unformatted — The representation type as specified is unaffected by any format transformations. This is the default value.

2. Printfile — The server is to transform data of either ASCII or EBCDIC type in accordance with ASA (Fortran) vertical format control standards. The data is to be transferred in 8-bit bytes.

A discussion of the ASA vertical format control appears in NWG/RFC 189, Appendix C, and in Communications of the ACM, Vol. 7, No. 10, p. 606, October 1964. According to the ASA vertical format control standards, the first character of a formatted record is not printed but determines vertical spacing as follows:

Character	Vertical Spacing before printing
Blank	One line
0	Two lines
1	To first line of next page
+	No advance

In addition to the above four, there are more characters (defined in Appendix C, RFC 189) which represent an IBM extension to the ASA standard.

It should be noted that a serving host need not accept all representation types and/or byte sizes, but it must inform the user requesting an unacceptable type or size of this fact by sending an appropriate reply.

III.C File Structure and Transfer Modes

The only file structures supported directly in FTP at the present time are record structures. However, the use of record structures is not mandatory. A user with no record structure in his file should be able to store and retrieve his file at any HOST. A user wishing to transmit a record structured file must

send the appropriate FTP 'STRU' command (the default assumption is no record structure). A serving HOST need not accept record structures, but it must inform the user of this fact by sending an appropriate reply. Any record structure information in the data stream may subsequently be discarded by the receiver.

All data transfers must end with an EOF. The EOF is defined by the data transfer mode. For files that have record structures, an EOR is also defined by the transfer mode. Only the transfer modes and representation type combinations that have EOR defined may be used for transfer of files with record structures. Records may be of zero length but they must be contained in file boundaries. The relationship between files and records is hierarchical but an EOF does not imply an EOR.

The following data transfer modes are defined in FTP:

1. Stream — The file is transmitted as a stream of bytes of the specified byte size. The EOF is signalled by closing the data connection. Any representation type and byte size may be used in the stream mode with file structure, but use of record structure limits the type to ASCII or EBCDIC with or without Printfile format. The convention is that the ASCII character CR (Carriage Return, Code 15 (octal)) followed by LF (Line Feed, Code 12 (octal)) indicates an EOR for ASCII representation type, and the EBCDIC character NL (New Line, Code 15 (hex)) indicates an EOR for EBCDIC type. This is the default mode, and it is recommended that this mode be implemented by all.

2. Text — The file is ASCII text transmitted as a sequence of 8-bit bytes in the ASCII representation type, and optional Printfile format. Record structures are allowed in this mode. The EOR and EOF are defined by the presence of special "TELNET-control" codes (most significant bit set to one) in the data stream. The EOR code is 192 (octal 300, hex C0). The EOF code is 193 (octal 301, hex C1). The byte size for transfer is 8 bits.

(For ASCII type, text and stream modes are almost identical.

Comparing the two, the advantages of "stream" mode are:

1) The receiver need not scan the incoming bytes.
2) It is usable with all data types.

and the disadvantages are:

1) Closing the data connection under error conditions can be misconstrued as an EOF in stream mode when in fact the data transfer was interrupted. In text mode the EOF is sent explicitly.
2) If record structure is specified in stream mode then CRLF implies EOR, and in order for CRLF to be sent as valid data it must be transformed, e.g., into CR NUL LF or LF CR.

3. Block — The file is transmitted as a series of data blocks preceded by one or more header bytes. The header bytes contain a count field, and descriptor code. The count field indicates the total length of the data block in bytes, thus marking the beginning of the next data block (there are no filler bits). The descriptor code defines last file block (EOF), last record block (EOR), restart marker (see Section III.D), or suspect data (i.e., the data being transferred is suspected of errors and is not reliable). Record structures are allowed in this mode, and any representation type or byte size may be used.

The header consists of the smallest integral number of bytes whose length is greater than or equal to 24 bits. Only the least significant 24 bits (right-justified) of header shall have information; the remaining most significant bits are "don't care" bits. Of the 24 bits of header information, the 16 low order bits shall represent byte count, and the 8 high order bits shall represent descriptor codes as shown below.

Integral data bytes ≥ 24

Don't care 0 to 231 bits	Descriptor 8 bits	Byte Count 16 bits

The following descriptor codes are assigned:

Code	Meaning
0	An ordinary block of data.
1	End of data block is EOR.
2	End of data block is EOF.
3	Suspected errors in data block
4	Data block is a restart marker.

In the use of block mode it is possible for two or more conditions requiring different descriptor codes (suspected errors and either end of record or end of file) to exist simultaneously. Such a possibility may be handled by sending a separate EOR or EOF block with a zero byte count. (This is allowed by the protocol.)

The restart marker is imbedded in the data stream as an integral number of 8-bit bytes (representing printable ASCII characters) right-justified in an integral number of data bytes greater than 8 bits. For example if the byte size is 7 bits, the restart marker byte would be one byte right-justified per two 7-bit bytes as shown below:

Two 7-bit bytes

	Marker Char 8 bits

For byte size of 16 bits or more, two or more marker bytes shall be packed right-justified. The end of the marker may be delimited by the character SP (code 32.). If marker characters do not exactly fit an integral byte, the unused character slots should contain the ASCII character SP (code 32.). For example, to transmit a six character marker in a 36-bit byte size, the following three 36-bit bytes would be sent:

Don't care 12 bits	Descriptor code=4	Byte count=2

	Marker 8 bits	Marker 8 bits	Marker 8 bits	Marker 8 bits

	Marker 8 bits	Marker 8 bits	SP 8 bits	SP 8 bits

4. Hasp — The file is transmitted as a sequence of 8-bit bytes in the standard Hasp-compressed data format (document tc be issued by Bob Braden, UCLA). This mode achieves considerable compression of data for print files. Record structures are allcwed in the Hasp mode.

The follcwing matrix summarizes the legal combinations of file transfer parameters. The decimal integers represent legal byte sizes for each particular STRU-MODE-TYPE-FORM grouping; absence of a number implies illegality. Note that HASP mode is not included since it has never been defined.

TYPE	STRU	F			R		
	MODE	S	T	B	S	T	B
	FORM						
A	U	8	8	8	8	8	8
	P	8	8	8	8	8	8
E	U	8		8	8		8
	P	8		8	8		8
I	U	1-255		1-255			1-255
L	U	1-255		1-255			1-255

III.D Error Recovery and Restart

There is no provision for detecting bits lost or scrambled in data transfer. This issue is perhaps handled best at the NCP level where it benefits most users. However, a restart procedure is provided to protect user from system failures (such as failure of either HOST, FTP-process, or the IMP subnet).

The restart procedure is defined only for the block mode of data transfer. It requires the sender of data to insert a special marker code in the data stream with some marker information. The marker information has meaning only to the sender, but must consist of printable ASCII characters. The printable ASCII characters are defined to be octal codes 41 through 176 (i.e., not including codes 0 through 37 and the characters SP and DEL). The marker could represent a bit-count, a record-count, or any other information by which a system may identify a data checkpoint. The receiver of data, if it implements the restart procedure, would then mark the corresponding position of this marker in the

receiving system, and return this information to the user.

In the event of a system failure, the user can restart the data transfer by identifying the marker point with the FTP restart procedure. The following examples illustrate the use of the restart procedure.

1. When server is the sender of data, the server-FTP process inserts an appropriate marker block in the data stream at a convenient data point. The user-FTP process, receiving the data, marks the corresponding data point in its file system and conveys the last known sender and receiver marker information to the user. In the event of system failure, the user or user-FTP process restarts the server at the last server marker by sending a restart command with the server's marker code as its argument. The restart command is transmitted over the TELNET connection and is immediately followed by the command (such as store or retrieve) which was being executed when the system failure occurred.

2. When user is the sender of data, the user-FTP process inserts the appropriate marker block in the data stream. The server-FTP process, receiving the data, marks the corresponding data point in its file system. The server does not store this marker but conveys the last known sender and receiver marker information to the user over the TELNET connections by appropriate reply codes. The user or the user-FTP process then restarts transfer in a manner identical to that described in the first example.

IV. FILE TRANSFER FUNCTIONS

The TELNET connections on which FTP commands and replies are transmitted are initiated by the user-FTP process via an ICP to a standard server socket. FTP commands are then transmitted from user to server, and replies are transmitted from server to user. The user file transfer functions involve sending the FTP commands, interpreting the replies received and transferring data over the data connection in the specified manner. The server file transfer functions involve accepting and interpreting FTP commands, sending replies, setting up the data connection, and transferring data.

IV.A FTP Commands

FTP commands are ASCII strings terminated by the ASCII character sequence CRLF (Carriage Return followed by Line Feed). The command codes themselves are ASCII alphabetic characters terminated by the ASCII character 'space' (octal code 40). For convenience, the command codes are defined to be four (or less) ASCII alphanumeric characters (including both upper and lower case alphabetic characters). The command codes and the semantics of commands are described in this section, but the detailed syntax of commands is specified in Section V.B, the reply sequences are discussed in Section V.C, and scenarios illustrating the use of commands are provided in Section V.D.

FTP commands may be partitioned as those specifying access-control identifiers, data transfer parameters, or FTP service

requests. Certain commands (such as ABOR, STAT, BYE) may be sent over the TELNET connections while a data transfer is in progress. Some servers may not be able to monitor the TELNET and data connections simultaneously, in which case these commands should be preceded by a TELNET SYNC to awaken the server. (For other servers this may not be necessary and the SYNC will be ignored.)

IV.A.1 Access Control Commands

The following commands specify access control identifiers (command codes are shown in parentheses).

User name (USER) - The argument field is an ASCII string identifying the user. The user identification is that which is required by the server for access to its file system. This command will normally be the first command transmitted by the user after the TELNET connections are made (some servers may require this). Additional identification information in the form of a password and/or an account command may also be required by some servers. Servers may allow a new USER command to be entered at any point in order to change the accounting information. All parameters are unchanged and any file transfer in progress is completed under the old account.

Password (PASS) - The argument field is an ASCII string identifying the user's password. This command must be immediately preceded by the user name command, and, for some sites, completes the user's identification for access control. Since password information is quite sensitive, it is desirable in general to "mask" it or suppress type out. It appears that the server has no foolproof way to achieve this. It is therefore the responsibility of the user-FTP process to hide the sensitive password information.

Account (ACCT) - The argument field is an ASCII string identifying the user's account. The command is not necessarily related to the USER command, as some sites may require an

account for login and others only for specific access, such as storing files. In the latter case the command may arrive at any time. There are two reply codes to differentiate these cases for the automaton: When account information is required for login and the server receives another command which he buffers, the legal response is reply code 331; when an account is required for a specific transfer requested, the reply code 433 is returned and the request command is flushed.

Reinitialize (REIN) - This command terminates a USER, flushing all I/O and account information, except to allow any transfer in progress to be completed. All parameters are reset to the default settings and the TELNET connection is left open. A USER command is expected to follow.

Logout (BYE) - This command terminates a USER and if file transfer is not in progress, closes the TELNET connection. If file transfer is in progress, the connection will remain open for result response and will then close. For "hot card-reader" mode the REIN command should be used instead.

An unexpected close on the TELNET connection will cause the server to take the effective action of an abort (ABOR) and a logout (BYE).

IV.A.2 Transfer Parameter Commands

All data transfer parameters have default values, and the commands specifying data transfer parameters are required only if the default parameter values are to be changed. The default value is the last specified value, or if no value has been specified, the standard default value as stated here. This implies that the server must "remember" the applicable default values. The commands may be in any order except that they must precede the FTP service request. The following commands specify data transfer parameters.

Byte size (BYTE) - The argument is an ASCII - represented decimal integer (1 through 255), specifying the byte size for the data connection. ~~for Local Byte and Image representation types.~~ The default byte size is 8 bits. The byte size is always 8 bits in the ASCII and EBCDIC representation types. A server may reject specific byte size/type combinations by sending an error reply code in response to a transfer request command.

Data socket (SOCK) - The argument is a HOST-socket specification for the data socket to be used in data connection. There may be two data sockets, one from server to user and the other for user to server data transfer. An odd socket number defines a send socket and an even socket number defines a receive socket. The default HOST is the user HOST to which TELNET connections are made. The default data sockets are (U+4) and (U+5) where U is the socket number used in the TELNET ICP and the TELNET connections are on sockets (U+2) and (U+3).

Listen (LSTN) - The argument is a single ASCII character code to specify the direction of the socket that the server must allocate for use as a data connection. The server is to "listen" on the allocated socket when an appropriate transfer command is given. The following codes are assigned:

S - send
R - receive

Representation Type (TYPE) - The argument is a single ASCII character code specifying the representation types described in Section III.B. The following codes are assigned for type:

A - ASCII
I - Image
L - Local Byte
E - EBCDIC

The default representation type is ASCII.

Format (FORM) - The argument is a single ASCII character code specifying the formats described in Section III.B. The following codes are assigned for format:

U - Unformatted
P - Printfile

The default format is Unformatted.

File Structure (STRU) - The argument is a single ASCII character code specifying file structure described in Section III.C. The

following codes are assigned for structure:

F - File (no record structure)
R - Record structure

The default structure is File (i.e., no records).

Transfer Mode (MODE) - The argument is a single ASCII character code specifying the data transfer modes described in Section III.C. The following codes are assigned for transfer modes:

S - Stream (bytes, close is EOF)
B - Block (header with descriptor and count)
T - Text (TELNET control code for EOR, EOF)
H - Hasp (specially formatted compressed data)

The default transfer mode is Stream.

IV.A.3 FTP Service Commands

The FTP service commands define the file transfer or the file system function requested by the user. The argument of an FTP service command will normally be a pathname. The syntax of path-names must conform to server site conventions (with standard defaults applicable), except that ASCII characters must be used (in conformance with the TELNET Protocol). The suggested default handling is to use the last specified device, directory or file name, or the standard default defined for local users. The commands may be in any order except that a "rename from" command, must be followed by a "rename to" command, and some servers may require an "allocate" command before a "store" command. The data, when transferred in response to FTP service commands, shall always be sent over the data connection. The following commands specify FTP service requests:

Retrieve (RETR) - This command achieves the transfer of a copy of the file specified in the pathname, from server to user site. The status and contents of the file at the server site shall be unaffected.

Store (STOR) - This command achieves the transfer of a copy of a file from user to server site. If the file specified in the pathname exists at the server site, then its contents shall be replaced by the contents of the file being transferred. A new file is created at the server site if the file specified in the pathname does not already exist.

Append (with create) (APPE) - This command achieves the transfer of data from using to serving site. If the file specified in the pathname exists at the server site, then the data transferred shall be appended to that file, otherwise the file specified in the pathname shall be created at the server site.

Allocate (ALLO) - This command may be required by some servers to reserve sufficient storage to accomodate the new file to be transferred. The argument field shall be a decimal integer representing the number of bytes (of size specified by the byte size command) of storage to be reserved for the file. This command shall be followed by a store or append command. The ALLO command should be treated as a NO-OP (no operation) by those servers which do not require that the maximum size of the file be declared beforehand.

Restart (REST) - The argument field represents the server marker at which file transfer is to be restarted. This command does not cause file transfer but "spaces" over the file to the specified data checkpoint. This command shall be immediately followed by the appropriate FTP service command which shall cause file transfer to resume.

Rename from - (RNFR) - This command specifies the file which is to be renamed. This command must be immediately followed by a "rename to" command specifying the new file pathname.

Rename to (RNTO) - This command specifies the new pathname of the file specified in the immediately preceding "rename from" command. Together the two commands cause a file to be renamed.

Abort (ABOR) - This command indicates to the server to abort the previous FTP service command and any associated transfer of data. The abort command should be preceded by the TELNET SYNCH condition (indicated by the combination of the DATA MARK and the INS). No action is to be taken if the previous command has been completed (including data transfer). The TELNET connections are not to be

closed by the server, but the data connection may be closed. An appropriate reply should be sent by the server.

Delete (DELE) - This command causes the file specified in the pathname to be deleted at the server site. If an extra level of protection is desired (such as the query, "Do you really wish to delete?"), it should be provided by the user-FTP process.

List (LIST) - This command causes a list to be sent from server to user site. If the pathname specifies a directory, the server should transfer a list of files in the specified directory. If the pathname specifies a file then server should send current information on the file. A null argument implies the user's current working or default directory. The data transfer is over the data connection in type ASCII or type EBCDIC. (It is the user's responsibility to ensure the correct parameters.)

NList (NLST) - This command causes a directory listing to be sent from server to user site. The pathname should specify a directory and the server will return a stream of names of files and no other information. The data will be transferred in ASCII or EBCDIC type over the data connection as valid pathname strings separated by CRLF. This command will allow automatic copying of an entire directory when used with the appropriate transfer commands.

Status (STAT) - This command shall cause a status response to be sent over the TELNET connection in form of a reply. The command may be sent during a file transfer (preceded by a TELNET SYNC) in which case the server will respond with the status of the operation in progress, or it may be sent between file transfers. In the latter case the command may have an argument field such as a pathname. If the argument is a pathname, the command is analogous to the "list" command except that data shall be transferred in ASCII on the TELNET connection. If a partial pathname is given, the server may respond with a list of file names or attributes associated with that specification. If no argument is given, the server should return general status information about the server FTP process. This should include current values of all transfer parameters and the status of connections.

Help (HELP) - This command shall cause the server to send helpful information regarding its implementation status over the TELNET connection to the user. The command may take an argument (e.g. any command name) and return more specific information as a response. The reply is type 100, general system status. It is suggested that HELP be allowed before entering a USER command.

Mail File (MLFL) - The intent of this command is to enable a user site to mail data (in form of a file) to another user at the server site. It should be noted that the files to be mailed are transmitted via the data connection in ASCII or EBCDIC type. (It is the user's responsibility to ensure that the type is correct.) These files should be appended to the destination user's mail by the server in accordance with serving HOST mail conventions. The mail may be marked as sent from the particular using HOST and the user specified by the 'USER' command. The argument field may contain one or more system or NIC idents (it is recommended that multiple idents be allowed so the same mail can easily be sent to several users), or it may be empty. If the argument field is empty or blank (one or more spaces), then the mail is destined for a printer or other designated place for site mail. A NIC ident refers to the standard identification described in the NIC Directory of Network Participants. A serving host may keep a table mapping NIC idents into system idents, although NIC idents are not required in the implementation. A system ident is the user's normal identification at the serving HOST. The use of system idents would allow a network user to send mail to other users who do not have NIC identification but whose system ident is known.

Mail (MAIL) - This command allows a user to send mail that is not in a file over the TELNET connection. The argument field may contain one or more system or NIC idents, or it may be empty. The idents are defined as above for the MLFL command. After the 'MAIL' command is received, the server is to treat the following lines as text of the mail sent by the user. The mail text is to be terminated by a line containing only a single period, that is, the character sequence ".CRLF" in a new line. It is suggested that a modest volume of mail service should be free; i.e., it may be entered before a USER command.

IV.A.4 Miscellaneous Commands

NoOp (NOOP) - This command does not affect any parameters or previously entered command. The server simply sends a no-op reply.

Qucte (QUOT) - This command allows the user to talk directly to the FTP-server. After parsing this command, the user-FTP process will pass without examination all succeeding liners until the NQUO command is received. Between these two commands the server will respond appropriately to his implementation and the user's requests.

NoQuote (NQUO) - This command returns the user and server processes to normal interactive mode. Both QUOT and NQUO have reply codes to be sent by the server process to the user process to ensure agreement on the current mode.

The quote commands provide a convenient method of testing server-implemented experimental commands. The names of the latter should begin with an X, and can be listed in the system HELP reply. It should be noted that the official command set is expandable; suggestions should go first to Alexander A. McKenzie (BBN).

IV.B FTP Replies

The server sends FTP replies over the TELNET connection in response to user FTP commands. The FTP replies constitute the acknowledgment or completion code (including errors). The FTP-server replies are formatted for human or program interpretation. Single line replies consist of a leading three-digit numeric code followed by a space, followed by a one-line text explanation of the code. For replies that contain several lines of text, the first line will have a leading three-digit numeric code followed immediately by the ASCII character "-" (Hyphen, Code 55 (octal)) and possibly some text. All succeeding continuation lines except the last are constrained not to begin with three digits; the last line must repeat the numeric code of the first line and be followed immediately by a space. For example:

```
100-First Line
Continuation Line
Another Line
100 Last Line
```

The numeric codes are assigned by groups and for ease of interpretation by programs in a manner consistent with other protocols such as the RJE protocol. The three digits of the code are to be interpreted as follows:

a) The first digit specifies type of response as indicated below:

000 These replies are purely informative and constitute neither a positive nor a negative acknowledgment.

1xx Informative replies to status inquiries. These constitute a positive acknowledgment to the status command.

2xx Positive acknowledgment of previous command or other successful action.

3xx Incomplete information. Activity cannot proceed without further specification and input.

4xx Unsuccessful reply. The request is correctly specified but the server is unsuccessful in correctly fulfilling it.

5xx Incorrect or illegal command. The command or its parameters were invalid or incomplete from a syntactic viewpoint, or the command is inconsistent with a previous command. The command in question has been completely ignored.

6xx-9xx Reserved for future expansion.

b) The second digit specifies the general category to which the response refers:

x00-x29 General purpose replies, not assignable to other categories.

x30 Primary access. Informative replies to the "log-on" attempt.

x40 Secondary access. The primary server is commenting on its ability to access a secondary service.

x5x FTP results.

x6x RJE results.

x7x-x9x Reserved for future expansion.

c) The final digit specifies a particular message type. Since the code is designed for an automation process to interpret, it is not necessary for every variation of a reply to have a unique number. Only the basic meaning of replies need have unique numbers. The text of a reply can explain the specific reason for that reply to a human user.

Each TELNET line delimited by a numeric code and CRLF (or group of text lines bounded by coded lines) that is sent by the server is intended to be a complete reply message. It should be noted that the text of replies is intended for a human user. Only the reply codes and in some instances the first line of text are intended for programs.

The assigned reply codes relating to FTP are:

000 General information message (site, time of day, etc.).
010 Message from system operator.
030 Server availability information.
050 FTP commentary or user information.
100 System status reply.
110 System busy doing...
150 File status reply.
151 Directory listing reply.
200 Last command received correctly.
201 An ABORT has terminated activity, as requested.
202 Abort request ignored, no activity in progress.
230 User is "logged in". May proceed
231 User is "logged out". Service terminated.
232 Logout command noted, will complete when transfer done.

233 User is "logged out". Parameters reinitialized.
250 FTP file transfer started correctly.
251 FTP Restart-marker reply.
        Text is: MARK yyyy = mmmm
        where yyyy is user's data stream marker (yours)
        and mmmm is server's equivalent marker (mine)
        (Note the spaces between the markers and '=').
252 FTP transfer completed correctly.
253 Rename completed.
254 Delete completed.
255 FTP server data socket reply
        Text is: SOCK nnnn
        where nnnn is a decimal integer representing
        the server socket for data connection
256 Mail completed.
300 Connection greeting message, awaiting input.
301 Current command incomplete (no CRLF for long time).
330 Enter password
331 Enter account (if account required as part of login sequence).
350 Enter mail, terminate by a line with only a '.'
400 This service not implemented.
401 This service not accepting users now, goodbye.
430 Log-on time or tries exceeded, goodbye.
431 Log-on unsuccessful. User and/or password invalid.
432 User not valid for this service.
433 Cannot transfer files without valid account. Enter account.
434 Log-out forced by operator action. Phone site.
435 Log-out forced by system problem.
436 Service shutting down, goodbye.
450 FTP: File not found.
451 FTP: File access denied to you.
452 FTP: File transfer incomplete, data connection closed.
453 FTP: File transfer incomplete, insufficient storage space.
454 FTP: Cannot connect to your data socket.
455 FTP: File system error not covered by other reply codes.
456 FTP: Name duplication; rename failed.
457 FTP: Transfer parameters in error.
500 Last command line completely unrecognized.
501 Syntax of last command is incorrect.
502 Last command incomplete, parameters missing.
503 Last command invalid (ignored), illegal parameter combination.
504 Last command invalid, action not possible at this time.
505 Last command conflicts illegally with previous command(s).
506 Requested action not implemented by the server.
507 Catchall error reply.
550 Bad pathname specification (e.g., syntax error).

V. DECLARATIVE SPECIFICATIONS

In order to make FTP workable without needless error messages, the following minimum implementation is required for servers:

```
TYPE — ASCII (with 8-bit bytes)
MODE — Stream
STRUCTURE — File
            Record (with ASCII type and CRLF
                    for EOR)
FORM — Unformatted
COMMANDS — USER, BYE, SOCK
           TYPE, BYTE, MODE, STRU, FORM
             for the default values
           RETR, STOR
           NOOP
```

The initial default values for transfer parameters are:

```
TYPE — ASCII
BYTE — 8
MODE — Stream
STRU — File
FORM — Unformatted
```

V.A Connections

The server-FTP process at the server site shall "listen" on Socket 3, via its server-TELNET. The user or user-FTP process at the user site shall initiate the full-duplex TELNET connections via its user-TELNET performing the ARPANET standard initial connection protocol (ICP) to server socket 3. Servers may specify that interaction over the TELNET connections be line-at-a-time with local echo. The server is not obliged to provide remote echo and may ignore TELNET control characters; he should not,

however, return error responses to the latter. All editing of command lines similarly must be local. The TELNET connections shall be closed by the user site upon completion of use and receipt of the last server reply.

The user site must "listen" on the specified data socket or sockets (a send and/or a receive socket). The server site shall initiate the data connection using the specified data socket and byte size. The direction of data connection and the data socket used shall be determined by the FTP service command. The server shall send a reply to the user indicating the server data socket so that the user may ensure the security of data transfer. This can be done at any time prior to the first transfer of data over a data connection. It should be emphasized that the user-FTP should not wait for a 255 (server data socket) reply before doing the "listen," since there is no guarantee that the reply will arrive before the user site ~~must send its~~ receives The initiating RFC. The security check can be done when the reply arrives and the data connection closed if it was made to a socket other than the one specified.

The data connection shall be closed by the server site under the conditions described in Section III.A. If the server wishes to close the connection in modes where that is not required, it is recommended that the close be sent immediately after the file transfer is completed rather than after a new transfer command is received, because the user or server may have to test the state of

the socket before doing a "listen" or "init." The server should in general send a reply before closing the data connection to avoid problems at the user end, though, for the reasons stated above, the user-FTP should not wait for the reply before doing his close.

V.B Commands

The commands are ASCII character strings transmitted over the TELNET connections as described in section IV.A. The command functions and semantics are described in sections IV.A.1, IV.A.2, IV.A.3, and IV.A.4. The command syntax is specified here.

The commands begin with a command code followed by an argument field. The command codes are four or less ASCII alphabetic characters. Upper and lower case alphabetic characters are to be treated identically. Thus any of the following may represent the retrieve command:

RETR Retr retr ReTr rETr

This also applies to any symbols representing parameter values, such as A or a for ASCII TYPE. The command codes and the argument fields are separated by one or more spaces.

The argument field consists of a variable length ASCII character string ending with the character sequence CRLF (Carriage Return immediately followed by Line Feed). In the following section on syntax it should be stressed that all characters in the argument

field are ASCII characters. Thus a decimal integer shall mean an ASCII represented decimal integer.

The following are all the currently defined FTP commands:

```
USER <username> CRLF
PASS <password> CRLF
ACCT <acctno> CRLF
REIN CRLF
BYE  CRLF
BYTE <byte size> CRLF
SOCK <HOST-socket> CRLF
LSTN <direction> CRLF
TYPE <type code> CRLF
FORM <form code> CRLF
STRU <structure code> CRLF
MODE <mode code> CRLF
RETR <pathname> CRLF
STOR <pathname> CRLF
APPE <pathname> CRLF
ALLO <decimal integer> CRLF
REST <marker> CRLF
RNFR <pathname> CRLF
RNTO <pathname> CRLF
ABOR CRLF
DELE <pathname> CRLF
LIST <pathname> CRLF
NLST <pathname> CRLF
STAT <pathname> CRLF
HELP <string> CRLF
MLFL <users> CRLF
MAIL <users> CRLF
NOOP CRLF
QUOT CRLF
NQUO CRLF
```

The syntax of the above argument fields (using BNF notation where applicable) is:

```
<username> ::= <string>
<password> ::= <string>
<acctno> ::= <string>
<string> ::= <empty>|<char>|<char><string>
<char> ::= any of the 128 ASCII characters except CR and LF.
<marker> ::= <pr string>
<pr string> ::= <empty>|<pr char>|<pr char><pr string>
<pr char> ::= any ASCII code 33 through 126.
<byte size> ::= any decimal integer 1 through 255.
<HOST-socket> ::= <socket>|<HOST number>,<socket>
<HOST number> ::= a decimal integer specifying an ARPANET HOST
<socket> ::= decimal integer between 0 and (2**32)-1
<direction> ::= S|R
<form code> ::= U|P
<type code> ::= A|E|I|L
<structure code> ::= F|R
<mode code> ::= S|B|T|H
<pathname> ::= <string>
<decimal integer> ::= <digit>|<digit><decimal integer>
<digit> ::= 0|1|2|3|4|5|6|7|8|9
<empty> ::= the null string (specifies use of default).
<users> ::= <user>|<user>,<users>
<user> ::= <empty>|<NIC ident>|<sys ident>
<NIC ident> ::= <string>
<sys ident> ::= <string>
```

V.C Sequencing of Commands and Replies

The communication between the user and server is intended to be an alternating dialogue. As such, the user issues an FTP command and the server responds with a prompt primary reply. The user should wait for this initial primary success or failure response before sending further commands.

A second type of reply is sent asynchronously with respect to user commands. These replies may, for example, report on the progress or completion of file transfer and as such are secondary replies to file transfer commands.

The third class of replies are informational and spontaneous replies which may arrive at any time. These replies are listed below as spontaneous.

COMMAND-REPLY CORRESPONDENCE TABLE

COMMAND	SUCCESS	FAIL
USER	230,330	430-432,500-505,507
PASS	230,331	430-432,500-507
ACCT	230	430-432,500-507
REIN	232,233	401,436,500-507
Secondary Reply	300	
BYE	231,232	430-432,500-505,507
BYTE	200,331	500-507
SOCK	200,331	500-505,507
LSTN	255,331	500-507
TYPE	200,331	500-507
FORM	200,331	500-507
STRU	200,331	500-507
MODE	200,331	500-507
RETR	250,331	433,450,451,454,455,457,500-505,507,550
Secondary Reply	252	452
STOR	250,331	433,451,454,455,457,500-505,507,550
Secondary Reply	252	452,453
APPE	250,331	433.451,454,455,457,500-507,550
Secondary Reply	252	452,453
ALLO	200,331	500-507
REST	200,331	500-507
RNFR	200,331	433,450,451,455,500-507,550
RNTO	253,331	433,450,451,455,456,500-505,507,550
ABOR	201,202,331	500-507
DELE	254,331	433,450,451,455,500-507,550
LIST	250,331	433,450,451,454,455,457,500-507,550
Secondary Reply	252	452
NLST	250,331	433,450,451,454,455,457,500-507,550
Secondary Reply	252	452
STAT	100,110,150,151,331	450,451,455,500-507,550
HELP	000,030,050,331	500-507
MLFL	250,331	433,450,451,454,455,457,500-507
Secondary Reply	252	452,453
MAIL	331,350	433,450,451,455,500-507
Secondary Reply	256	
NOOP	200	500-505,507
QUOT	200,331	500-507
NQUO	200	500-505,507
Spontaneous Replies	0xx,300,301 251,255	400,401,434-436

V.D Typical FTP Scenarios

1. TIP User wanting to transfer file from HOST X to local printer:

   a) TIP user opens TELNET connections by ICP to HOST X, socket 3.

   b) The following commands and replies are exchanged:

```
TIP                                   HOST X

USER username CRLF -------->
<-------- 330 Enter PasswordCRLF

PASS password CRLF -------->
<-------- 230 User logged inCRLF

SOCK 65538 CRLF    -------->
<-------- 200 Command received OKCRLF

RETR this.file CRLF -------->
<-------- 255 SOCK 5533CRLF

(HOST X initiates data connection to
 TIP socket 65538, i.e., PORT 1 receive)

<-------- 250 File transfer started

BYECRLF            -------->
<-------- 252 File transfer completed
```

   c) HOST X closes the TELNET and data connections.

   Note: The TIP user should be in line mode.

2. User at HOST U wanting to transfer files to/from HOST S:

   In general the user would communicate to the server via a mediating user-FTP process. The following may be a typical scenario. The user-FTP prompts are shown in parentheses, '---->' represents commands from HOST U to HOST S, and '<-----' represents replies from HOST S to HOST U.

Local Commands by User	Action Involved
ftp (host) multicsCR	ICP to HOST S, socket 3, establishing TELNET connections.
username Doe CR	USER DoeCRLF ---->
	<----- 330 passwordCRLF
password mumble CR	PASS mumbleCRLF ---->
	<----- 230 Doe logged in.CRLF

```
retrieve (local type) ASCIICR
(local pathname) test 1 CR
(for.pathname) test.pl1CR

type ImageCR

byte 36CR

store (local type) imageCR
(local pathname) file dumpCR
(for.pathname) >udd>cn>fdCRF

terminate
```

```
User-FTP opens local file in ASCII.
RETR test.pl1CRLF ---->
<---- 255 SOCK 1233CRLF
Server makes data connection to (U+4).
<---- 250 File transfer startsCRLF
<---- 252 File transfer completeCRLF
TYPE ICRLF ---->
<---- 200 Command OKCRLF
BYTE 36CRLF ---->
<---- 200 Command OKCRLF

User-FTP opens local file in Image.
STOR >udd>cn>fdCRLF ---->
<---- 451 Access deniedCRLF
<---- 231 Doe logged outCRLF
Server closes all connections.
```